PATENT
PD-970134A

COMMUNICATION SYSTEM EMPLOYING REUSE OF SATELLITE SPECTRUM FOR TERRESTRIAL COMMUNICATION

William. W. Mayfield
Donald. C. Chang
John I. Novak III

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of Serial No. 09/105,622, filed June 26, 1998, the entire contents of which are incorporated herein by this reference.

BACKGROUND OF THE INVENTION

(a) Field of the Invention

This invention relates generally to a communications system and method wherein multiple communication systems are integrated into a common allocated radio frequency spectrum. More particularly, it relates to a communications system and method that integrates a terrestrial communication system into the radio frequency spectrum allocated to a mobile satellite communication system.

(b) Description of Related Art

Terrestrial communication services such as voice cellular and Personal Communication Systems (PCS) transmit information within a narrow spectrum surrounding nominal frequencies of 900 MHZ and 2 GHz respectively. The available spectra for such terrestrial communications are scarce and expensive. To operate their businesses profitably, companies providing these terrestrial communication services must maximize the number of users on their allocated frequency spectrum. This is accomplished by first sub-dividing the allocated spectrum into numerous spectra or frequency bands, and then sub-dividing large geographic areas into numerous spatially isolated communication cells. Thus, each cell can support numerous users on its multiple frequency bands, and reuse of these frequency bands across cells permits multiple users to use the same frequency band as long as they are in spatially isolated cells..

Mobile Satellite Service (MSS) providers such as the American Mobile Satellite Corporation (AMSC) provide satellite communication services through

networks of mobile satellites in geosynchronous earth orbit (GEO). Other MSS providers operate satellite networks in medium earth orbit (MEO), and low earth orbit (LEO). The Federal Communications Commission (FCC) has allocated a 34 MHZ spectrum within the L-band (at 1.5 GHz) for use in mobile satellite communications. MSS providers share this 34 MHZ spectrum globally. As with the terrestrial communication providers, MSS providers can improve their profitability by maximizing the number of users on their allocated frequency spectrum. Traditionally, this has been accomplished using specific antenna designs and locations that provide spatial or geographic isolation and then reusing frequency bands across the isolated areas.

Thus, there is a need for a system and method of integrating multiple communication systems into a common allocated radio frequency spectrum. More specifically, there is a need for a system and method that integrates a terrestrial communication system into the radio frequency spectrum allocated to a mobile satellite communication system.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, a terrestrial communication system comprises a terrestrial cell site that produces a signal at a satellite uplink frequency and transmits it to a terrestrial user terminal, and that receives a signal at a satellite downlink frequency that was transmitted by a terrestrial terminal unit.

In accordance with another aspect of the present invention, a terrestrial communication system comprises a terrestrial terminal unit that produces a signal at a satellite downlink frequency and transmits it to a terrestrial cell site, and that receives a signal at a satellite uplink frequency that was transmitted by a terrestrial cell site.

In accordance with yet another aspect of the present invention, a method of integrating a terrestrial communication system into a satellite communication frequency spectrum comprises the following steps: a) producing a signal at a satellite uplink frequency that is transmitted from a terrestrial cell site to a terrestrial user terminal, and b) receiving a signal at a satellite downlink frequency that was produced by said terrestrial user terminal and transmitted to a terrestrial cell site.

The invention itself, together with further objects and attendant advantages, will best be understood by reference to the following detailed description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a system level diagram of a terrestrial communication system according to a preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is highly desirable to develop a system and method for integrating a terrestrial communication system into the radio frequency spectrum allocated to a mobile satellite communication system so that MSS providers can expand their business to include millions of potential terrestrial customers. Such an expanded customer base would substantially increase an MSS provider's profitability by allowing greater utilization of their allocated spectrum.

MSS providers have been unable to integrate terrestrial communication services into their allocated frequency spectrum because conventional systems and methods of reusing frequency bands would produce intolerable levels of mutual interference. There are several difficulties inherent in integrating a terrestrial communications system into an existing satellite communication system. First, a satellite beam covers a large geographic area which could include a large number of terrestrial communication cells. Thus, a large number of terrestrial users could generate an intolerable level of aggregate interference on the satellite uplink frequency bands. Second, satellite downlink interference could impinge on a large group of terrestrial users within the scope of the satellite's beam. Third, eliminating or minimizing these interferences would require incorporation of special electronic filtering and directional antennas into a variety of hand-held terrestrial user terminals. Such design modifications are not practical because of the need for mobility, small size, and low cost in these units.

The present invention overcomes these difficulties by reversing the transmission and reception frequency bands for the terrestrial user relative to the satellite user in combination with modification of terrestrial cell site antennas to include pattern nulls in the direction of mobile satellites.

Figure 1 shows one preferred embodiment for the present invention. The system 10 depicted in FIG. 1 reverses the transmission and reception frequency bands of the terrestrial communication system, represented by cell site 12, with respect to the satellite communication system represented by satellite 14. Terrestrial user terminals 18 transmit on the satellite system's downlink frequency (f_d) and receive communications on the satellite system's uplink frequency (f_u). This relative reversal of frequency bands shifts potential interference paths so that their impact can be more easily minimized or eliminated.

With the present invention, interference between the large number of terrestrial users and satellites has been completely eliminated. Additionally, interference between cell sites and satellite ground users has been completely eliminated.

The system shown in FIG. 1 creates four potential interference paths: (1) terrestrial cell site transmission can interfere with satellite uplinks, (2) satellite transmissions can interfere with cell site reception, (3) terrestrial user terminal transmissions can interfere with satellite ground user reception, and (4) satellite ground user transmissions can interfere with terrestrial user terminal reception. Using the disclosed system, mutual interference paths have shifted, and exist between terrestrial users 18 and ground satellite users 16, and also between cell sites 12 and satellites 14.

Mutual interference between terrestrial users 18 and satellite users 16 is easily minimized to tolerable levels through geographic isolation of frequency reuse. MSS providers are typically allocated multiple uplink and multiple downlink frequency bands. Assigning frequency bands so that terrestrial users 18 and ground satellite users 16 within the same geographic region are using different uplink and downlink bands minimizes the potential for interference within a region.

Mutual interference between cell sites 12 and satellites 14 is reduced to tolerable levels by adding pattern nulls to terrestrial cell site antennas. Adding pattern nulls to cell site antennas that block satellite interference will not

ordinarily impair the quality of terrestrial communications because the desired radiation pattern for cell sites is predominantly horizontal. Furthermore, the additional cost of these cell site pattern nulls will not be prohibitive since there are relatively few cell site installations for a large number of terrestrial users.

Terrestrial user cell site antennas can be designed with high gain in the horizontal directions and with fixed nulls towards satellite directions. For example, simple sidelobe canceling techniques result in a 10 dB to 20 dB gain in the desired direction for terrestrial communications, and a -35 dB to -55 dB attenuation in the mobile satellite directions. More complex nulling techniques may be used to further improve the discrimination of the cell site antennas. For example, low gain elements may be added to the main antenna elements. Each low gain element would provide an independent null in an interference direction, and their amplitudes and phases can be adjusted so that they add destructively.

Low gain elements tend to produce narrow band nulls in a given direction. Wide band nulls can be formed to cover both the transmit and receive frequency bands (about 1 GHz separation) by using multiple low gain elements for each interference direction, or by using multiple taps on a single low gain element to produce nulls at multiple frequencies. Cost considerations will favor a multiple tap approach for low bandwidth digital applications, and the extra element approach for high bandwidth analog applications.

Of course, it should be understood that a range of changes and modifications can be made to the preferred embodiment descibed above. For example, more complex weighting control of the signals from the various antenna elements can be used to further improve the discrimination of terrestrial cell site antennas. Nulls of -30 dB can be achieved with a control resolution of 8 bits. Finally, a dynamic adjustment of the antenna nulls would permit the application of the present invention to satellites that are not in geosynchronous orbit. Dynamic control of the null signal weighting using a table look-up can be accomplished within a simple closed loop feedback system employing a steepest descent search algorithm and a least-mean-square as the optimization criteria. Thus, MSS providers having MEO and LEO satellite networks would

thereby benefit by being able to use their allocated frequency spectrum in terrestrial applications.

It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it be understood that it is the following claims, including all equivalents, which are intended to define the scope of this invention.